

## INVASIVE SPECIES OF MEALYBUGS (HEMIPTERA: PSEUDOCOCCIDAE) AND THEIR THREAT TO U.S. AGRICULTURE

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*Abstract.*—We provide a compilation of 158 species of mealybugs that are either a pest or threat to United States agriculture. Included for each species, where applicable, is reference to: the United States origin and date of introduction; whether it is established in the United States; its pest or threat status in the United States along with a validation citation; its principle hosts; and its biogeographical region of origin.

*Key Words:* Pseudococcidae, mealybugs, invasive species, biological control, agriculture

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Mealybugs (Pseudococcidae) are major agricultural pests and pose serious problems when introduced into new areas of the world without natural enemies. In recent years, it has become increasingly obvious that introduced species have a major economic and esthetic impact on plants. Public concern stimulated Congress to develop a report on the subject (Office of Technology Assessment 1993) and a Presidential initiative (Executive Order 13112) to seek a solution to this problem is currently underway. Scale insects are notorious invaders because they are small, often live in concealed habitats, and frequently are transported on commodities that are common in international commerce. Mealybugs are a group of scale insects that are of special interest because of the recent introduction of four pest species in the United States. They are: the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) (California 1999), the papaya mealybug, *Paracoccus marginatus* Williams and Granara de Wil-

link (Florida 1998), the vine mealybug *Planococcus ficus* (Signoret) (California 1994), and the banana mealybug *Pseudococcus elisae* Borchsenius (Florida 1995). The origin of recent California infestations of *P. ficus* is not clear. This species was collected in several localities in the southeastern United States beginning in 1924, but was always found on fig trees (*Ficus carica* L.). It has not been recollected since 1959 and was never collected east of Texas. The infestation in California is only on grapes and has not been found on figs. It is likely that the California infestation is from an overseas source and not from the eastern United States.

Since invasive species are a major issue in U.S. agriculture, and with several recent introductions of pest mealybug species, we decided to investigate several parameters concerning invasive mealybug species. Our objectives were: 1) to develop a preliminary list of the pest mealybug species of the world; 2) to provide a list of introduced and

pest mealybugs of the United States; 3) to ascertain which of the species in the previous two objectives are introduced or native to the United States; 4) to examine data provided by the United States Department of Agriculture, Animal and Plant Health Inspection Service—Plant Protection and Quarantine (USDA, APHIS-PPQ) concerning the most commonly intercepted mealybug species at the United States ports-of-entry; and 5) using this information, to try to understand which mealybugs are most likely to invade the United States in the future.

#### MATERIALS AND METHODS

Executive Order 13112 established the National Invasive Species Council and provided a definition of an invasive species as: "... a species that is 1) non-native (or alien) to the ecosystem under consideration **and** 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health." This definition not only includes alien species to the United States but also encompasses native species. The definition also has an economic or potential economic component. Using this definition, the grape mealybug, *Pseudococcus maritimus* (Ehrhorn) would be an example of an invasive species in the United States even though it likely is native. The definition that we use is a bit more simplistic. We consider invasive species to be those that are not native to the United States (alien or adventive) regardless of economic harm.

To make a table of pest mealybugs of the world, we have used a broad definition of the term "pest." Essentially, if a species is described in the literature as a pest, or as causing damage, or being controlled, or of economic importance, we have included it in the list. Our perspective for this paper has focused on the impact or potential impact of a pest mealybug in the United States. For example, *Antonina pretiosa* Ferris is known only from bamboo, and therefore, is considered to have relatively minor

pest potential in the United States; it may be far more important in areas of the world where bamboo is a predominant component of the natural or ornamental vegetation. Conversely, *Pseudococcus cryptus* Hempel occurs on an array of agricultural crops that are important to the United States economy and is considered a major threat. The term "threat" is used for species that are considered pests but do not occur in the United States. For adventive species, we have approximated the United States date of introduction by searching the literature for the earliest collection record or have examined specimens in the National Entomological Collection of the National Museum of Natural History, in Beltsville, Maryland for the earliest record. Obviously, these dates are only estimates of when the species first invaded the United States. It is difficult to determine the zoogeographic area of origin for some species. It is clear that they are from the old or new world, but it is not always evident from which area. In some cases, we have simply made an educated guess based on the current distribution of the species, the distribution of what appears to be its closest relatives, and the natural distribution of its primary host plants. We have used the same criteria to determine if a particular species is native to the United States. In several instances, it is not clear, e.g., *Phenacoccus gossypii* Townsend and Cockerell or *P. dearnesii* King.

#### RESULTS

Table 1 provides information on 158 mealybug species. Since the table includes six species that have been introduced into the United States but are not considered pests, we estimate that there are 152 mealybugs that represent either a pest or threat to the United States agriculture. In the United States, there are 66 pest mealybug species, 19 are considered to be native. Therefore, 47 mealybug pests in the country are invasive species. Based on information presented in ScaleNet on the Pseudococcidae by Ben-Dov and German (2001), there are

Table 1. Pest or threat mealybug species to United States agriculture. Abbreviation for origin are: Afrotropical Region (AF); Australasian Region (AU); Nearctic (NE); Neotropical Region (NT); Oriental Region (OR); Palearctic Region (PA).

Pest or Threat species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference to Threat or Pest Status	Principle Hosts	Origin
<i>Antonina crani</i> Cockerell	CA, 1900	yes	minor pest	Sasseer 1918	bamboo	PA
<i>Antonina graminis</i> (Maskell)	TX, 1942	yes	pest	Ben-Dov 1994	grass	OR
<i>Antonina pretiosa</i> Ferris	CA, 1925	yes	minor pest	Ferris 1953	bamboo	PA
<i>Atracoccus bejbiankoi</i> Kozár and Danzig		no	minor threat	Kozár and Kozár 1988	raspberry	PA
<i>Balanococcus diminutus</i> (Leonardi)	CA, 1906	yes	pest	Saakyán-Baranova 1954	Phormium	AU
<i>Balanococcus poae</i> (Maskell)		no	major threat	Cox 1987	rye grass	AU
<i>Birendracoccus saccharifolii</i> (Green)		no	threat	Ali 1962	sugar cane	OR
<i>Brevantia rehi</i> (Lindinger)	CA, AZ, 1967	yes	pest	Ben-Dov 1994	grass	OR
<i>Cataenococcus hispidus</i> (Morrison)		no	major threat	Azhar 1983	many tropical hosts	OR
<i>Chaetococcus bambusae</i> (Maskell)	MD, 1952	yes	not a pest		bamboo	PA
<i>Chaetococcus phragmitis</i> (Marchal)	NJ, 1975	yes	not a pest		phragmites	PA
<i>Crisicoccus azaleae</i> (Tinsley)	CA, 1898	yes	pest	Fox-Wilson 1939	azalea	PA
<i>Crisicoccus matsutomoi</i> (Siraawa)		no	threat	Park and Hong 1992	fruit trees	PA
<i>Crisicoccus pini</i> (Kuwana)	CA, 1918	yes	not a pest		pine	PA
<i>Coccinea sinuata</i> (Kuwana and Toyoda)		no	threat	Danzig 1986	fruit and ornamentals	PA
<i>Coccidolystrix insolita</i> (Green)		no	threat	Krishnamoorthy and Mani 1996	egg plant	PA
<i>Deltoctococcus euphorbiae</i> (Ezzat and McConnell)		no	threat	Marotta and Pagano 1997	succulents	AF?
<i>Dysmicoccus angustus</i> (Ezzat and McConnell)	?, 1912	yes	not a pest?		bamboo	OR
<i>Dysmicoccus boninis</i> (Kuwana)	FL, 1895	yes	minor pest	Ben-Dov 1994	sugar cane	PA
<i>Dysmicoccus bispinosus</i> Beardsley		no	minor threat	García 1995	tropical hosts	NE
<i>Dysmicoccus brevipes</i> (Cockerell)	FL, 1880	yes	minor pest	Ben-Dov 1994	polyphagous	NT
<i>Dysmicoccus carens</i> Williams		no	threat	Razak et al. 1994	sugarcane	OR
<i>Dysmicoccus cocotis</i> (Maskell)		no	threat	Williams and Watson 1988	palms	OR
<i>Dysmicoccus russii</i> (Leonardi)	FL, 1966	yes	pest	Williams and Gramara de Willink 1992	polyphagous	NT
<i>Dysmicoccus neobrevipes</i> Beardsley		no	threat	Williams and Watson 1988	polyphagous	NT
<i>Dysmicoccus vaccinii</i> Miller and Polavarapu	native	yes	pest	Miller and Polavarapu 1997	blueberry	NE
<i>Dysmicoccus wistariae</i> (Green)	NJ, 1915	yes	pest	Hamilton 1942	taxus	PA
<i>Elatomía cupressi</i> (Ehrhorn)	native	yes	pest	Brown and Eads 1967	cypress	NE
<i>Ferrisia madvastra</i> (McDaniel)	FL, 1918	yes	pest	Williams 1996	polyphagous	NT(?)
<i>Ferrisia virgata</i> (Cockerell)	NM, 1896	yes	pest	Ben-Dov 1994	polyphagous	NT(?)
<i>Geococcus citrinus</i> Kuwana		no	threat	Huang 1987	citrus	OR

Table 1. Continued.

Pest or Threat species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference to Threat or Pest Status	Principle Hosts	Origin
<i>Geococcus coffeae</i> Green	1958	no	threat	Williams and Granara de Willink 1992	polyphagous, including coffee	OR
<i>Heliococcus bohemicus</i> Šalč		no	major threat	Kozziarab and Kozár 1988	grape	PA
<i>Heliococcus summervillei</i> Brookes		no	minor threat	Summerville 1928	grass, including sugar cane	AU
<i>Heterococcus nigertensis</i> Williams		no	threat	Harris 1961	sorghum	AF
<i>Heterococcus nudus</i> (Green)	NH, 1921	yes	pest	McKenzie 1967	grass	PA
<i>Heterococcus tritici</i> (Kiritschenko)		no	threat	Kiritschenko 1932	wheat	PA
<i>Hypogeoecus festerianus</i> (Lizer and Trelles)		no	minor threat	Marotta and Garonna 1992	cactus	NT
<i>Hypogeoecus spinosus</i> Ferris	CA, 1951	yes	minor pest	Ben-Dov 1994	cactus	NE
<i>Idiococcus banthusae</i> Takahashi and Kanda	NJ, 1916	yes	not a pest		bamboo	PA
<i>Kiritshenkella sacchari</i> (Green)		no	minor threat	Williams 1970	sugar cane	OR
<i>Maconellicoccus australianus</i> (Green and Lidgett)		no	minor threat	Brookes 1972	acacia	AU
<i>Maconellicoccus hirsutus</i> (Green)	CA, 1999	yes	major pest	Ben-Dov 1994	polyphagous	OR
<i>Maculicoccus malaitensis</i> (Cockerell)		no	threat	Cockerell 1929	tropical plants	AU
<i>Melanococcus albizziae</i> (Maskell)		no	threat	Williams 1985a	acacia	AU
<i>Miscanthicoccus miscanthi</i> (Takahashi)	MD, VA, 1989	yes	minor pest	Stimmel 1996	miscanthus	OR(?)
<i>Mizococcus sacchari</i> Takahashi		no	minor threat	Takahashi 1928	sugar cane	OR
<i>Neochavesia caldasiae</i> (Balachowsky)		no	minor threat	Balachowsky 1957	coffee	NT
<i>Nipaeococcus aurilantatus</i> (Maskell)	CA, 1912	yes	minor pest	Brown and Eads 1967	auracaria	AU
<i>Nipaeococcus nipae</i> (Maskell)	CA, 1897	yes	pest	Ben-Dov 1994	polyphagous	NT
<i>Nipaeococcus viridis</i> (Newstead)		no	major threat	Sharaf and Meyerdirk 1987	polyphagous	OR(?)
<i>Oracella acuta</i> (Lobdell)	native	yes	minor pest	Gu and Chen 1996	pine	NE
<i>Palmicallithor browui</i> (Williams)	FL, 1995	yes	not a pest		palm	PA
<i>Palmicallithor palmarium</i> (Ehrhorn)	FL, 1999	yes	minor pest	Hara et al. 1996	citrus	OR(?)
<i>Paracoccus burmerae</i> (Brain)		no	threat	Hattingh 1993	juniper	AF
<i>Paracoccus juniperi</i> (Ehrhorn)	native	yes	minor pest	Calkins 1946	polyphagous	NE
<i>Paracoccus marginatus</i> Williams and Granara de Willink	FL, 1998	yes	pest	Williams and Granara de Willink 1992	polyphagous	NE
<i>Paraputo leverii</i> (Green)		no	minor threat	Williams 1987a	coffee	AF
<i>Paraputo tarakogeni</i> Rao		no	threat	Rao 1950	chaulmoogra tree and tea	OR
<i>Peliococcus perfidiosus</i> Borchsenius		no	threat	Kozziarab and Kozár 1988	tobacco, potato	PA
<i>Phenacoccus acericola</i> King	native	yes	pest	Johnson and Lyon 1991	sugar maple	NE
<i>Phenacoccus aceris</i> (Signoret)	ME, 1933	yes	pest	Ben-Dov 1994	polyphagous (trees)	PA
<i>Phenacoccus avenae</i> Borchsenius		no	major threat	Williams and Miller 1985	???bulbs????	PA

Table 1. Continued.

Pest or Threat species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference to Threat or Pest Status	Principle Hosts	Origin
<i>Phenacoccus azaleae</i> Kuwana	IL, 1894	no	major threat	Xie et al. 1998	azalea	PA
<i>Phenacoccus dearnessi</i> King	native	yes	pest	Cranshaw et al. 1998	fruit trees	PA(?)
<i>Phenacoccus defectus</i> Ferris	native	yes	pest	Malumphy 1997	succulents	NE
<i>Phenacoccus emansor</i> Williams and Kozartshvetskaya	native?	no	threat	Pijls et al. 1998	iris bulbs	PA
<i>Phenacoccus gossypii</i> Townsend and Cockerell	CA, 1953	yes	pest	McKenzie 1967	polyphagous	NE
<i>Phenacoccus graminicola</i> Leonard	native?	yes	pest	Ward 1966	apples	PA
<i>Phenacoccus herreni</i> Cox and Williams	native?	no	threat	Castillo and Bellotti 1990	cassava	NT
<i>Phenacoccus horadet</i> (Lindeman)	native?	no	minor threat	Kosztarab and Kozár 1988	grass	PA
<i>Phenacoccus madeirensis</i> Green	native	yes	pest	Castillo and Bellotti 1990	polyphagous	NT
<i>Phenacoccus manihoti</i> Matile-Ferrero	native	no	minor threat	Ben-Dov 1994	cassava	NT
<i>Phenacoccus minutus</i> Tinsley	FL, 1983	yes	pest	Doane et al. 1936	spruce	NE
<i>Phenacoccus parvus</i> Morrison	native	yes	pest	Williams and Watson 1988	polyphagous	NT
<i>Phenacoccus piceae</i> (Low)	FL, 1983	yes	pest	Kosztarab and Kozár 1988	<i>Picea</i>	PA
<i>Phenacoccus pumilus</i> Kiritshenko	native	no	minor threat	Kosztarab and Kozár 1988	pine	PA
<i>Phenacoccus solani</i> Ferris	native	yes	pest	Dudley et al. 1952	polyphagous	NE
<i>Phenacoccus solenopsis</i> Tinsley	native	yes	minor pest	Fuchs et al. 1991	cotton	NE
<i>Phenacoccus tegrigoriana</i> Borchsenius	FL, 1880	no	threat	Ter-Grigorian 1956	cereals	PA
<i>Planococcoides njalensis</i> (Laing)	FL, 1880	no	minor threat	Dufour 1991	cacao	AF
<i>Planococcus citri</i> (Risso)	LA, 1924	yes	pest	Ben-Dov 1994	polyphagous	OR
<i>Planococcus dioscoreae</i> Williams	CA, 1994	no	minor threat	Williams 1960	yams	AU(?)
<i>Planococcus ficus</i> (Signoret)	CA, 1994	yes	pest	Ben-Dov 1994	polyphagous	PA
<i>Planococcus fungicola</i> Watson and Cox	MD, 1978	no	minor threat	Watson and Cox 1990	coffee	AF
<i>Planococcus hali</i> Ezzat and McConnell	CA, 1915	no	minor threat	Cox 1989	yams	AF
<i>Planococcus japonicus</i> Cox	MD, 1978	yes	pest	Cox 1989	azalea	PA
<i>Planococcus kenya</i> (Le Pelley)	CA, 1915	no	minor threat	Le Pelley 1943	coffee	AF
<i>Planococcus kranthiae</i> (Kuwana)	CA, 1915	yes	pest	Park and Hon 1992	polyphagous	PA
<i>Planococcus lilacinus</i> (Cockerell)	CA, 1915	no	major threat	Ben-Dov 1994	polyphagous	AF(?)
<i>Planococcus litchi</i> Cox	CA, 1915	no	minor threat	Cox 1989	lychee	PA(?)
<i>Planococcus mali</i> Ezzat and McConnell	CA, 1915	no	minor threat	Cox 1989	currants	PA(?)
<i>Planococcus minor</i> (Maskell)	CA, 1915	no	major threat	Ben-Dov 1994	polyphagous	OR
<i>Planococcus musae</i> Matile-Ferrero and Williams	CA, 1994	no	threat	Matile-Ferrero and Williams 1995	plantain	AF

Table 1. Continued.

Pest or Threat species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference to Threat or Pest Status	Principle Hosts	Origin
<i>Planococcus radicum</i> Watson and Cox		no	threat	Watson and Cox 1990	coffee	OR
<i>Planococcus vovae</i> (Nasonov)		no	threat	Williams 1984	cypress	PA
<i>Polystomophora ostiapharina</i> (Kiritschenko)		no	threat	Kosztarab and Kozár 1988	trees	PA
<i>Pseudococcus apionicircitulus</i> Gimpel and Miller		no	threat	Gimpel and Miller 1996	orchids	NE
<i>Pseudococcus talcecolariæ</i> (Maskell)	CA, 1915	yes	pest	Ben-Dov 1994	polyphagous, including citrus	AU(?)
<i>Pseudococcus comstocki</i> (Kuwana)	DC, 1906	yes	pest	Ben-Dov 1994	fruit trees and ornamental plants	PA
<i>Pseudococcus cryptus</i> Hempel		no	major threat	Ben-Dov 1994	citrus	NT(?)
<i>Pseudococcus dendrobium</i> Williams		no	threat	Williams 1985a	orchids	AU
<i>Pseudococcus dolichoneelos</i> Gimpel and Miller	native	yes	pest	Gimpel and Miller 1996	polyphagous	NE
<i>Pseudococcus elisæ</i> Borchsenius	FL, 1995	yes	pest	Gimpel and Miller 1996	polyphagous	NT
<i>Pseudococcus imparitatus</i> McKenzie	NJ, MD, 1941	yes	minor pest	Johnston 1964	orchids	NT
<i>Pseudococcus jackbeardsleyi</i> Gimpel and Miller	FL, 1921	yes	pest	Gimpel and Miller 1996	polyphagous	NT
<i>Pseudococcus landoi</i> (Balachowsky)		no	threat	Williams and Granara de Willink 1992	polyphagous	NT
<i>Pseudococcus longispinus</i> (Targioni Tozzetti)	DC, 1881	yes	major pest	Ben-Dov 1994	polyphagous	AU
<i>Pseudococcus mandio</i> Williams		no	minor threat	Gimpel and Miller 1996	cassava	NT
<i>Pseudococcus maritimus</i> (Ehrhorn)	native	yes	pest	Ben-Dov 1994	grape and fruit trees	NE
<i>Pseudococcus microdonidum</i> Beardsley		no	minor threat	Williams 1981	coconut	AU
<i>Pseudococcus microcirculus</i> McKenzie		yes	minor pest	McKenzie 1967	orchids	NT
<i>Pseudococcus nakaharai</i> Gimpel and Miller	CA, 1954	yes	minor pest	Gimpel and Miller 1996	cactus	NE
<i>Pseudococcus olearum</i> Miller and Williams	DC, 1890	yes	minor pest	Miller and Williams 197	citrus	OR
<i>Pseudococcus perigrinabundus</i> Borchsenius	FL, 1973	yes	pest	Gimpel and Miller 1996	citrus	OR
<i>Pseudococcus saccharicola</i> Takahashi		no	minor threat	Gimpel and Miller 1996	banana	NT
<i>Pseudococcus solenidos</i> Gimpel and Miller		no	threat	Williams 1970	sugar cane	PA
<i>Pseudococcus sordidellus</i> (Forbes)	native	yes	threat	Gimpel and Miller 1996	tropical fruit	NE
<i>Pseudococcus spanocera</i> Gimpel and Miller	native	yes	pest	Gimpel and Miller 1996	beans, clover	NE
<i>Pseudococcus viburni</i> (Signoret)	native	yes	pest	Gimpel and Miller 1996	soybeans	NE
<i>Pseudoripsteria turripes</i> (Maskell)	native	yes	pest	Ben-Dov 1994	polyphagous	NE
<i>Puto barberti</i> (Cockerell)		no	threat	Williams 1985a	caesuarina	AU
		no	major threat	Williams and Granara de Willink 1992	polyphagous	NT
<i>Puto pilosellæ</i> (Štule)		no	minor threat	Kosztarab and Kozlar 1988	strawberries	PA
<i>Rastrococcus iceryoides</i> (Green)		no	major threat	Le Pelley 1968	coffee and mango	AF(?)
<i>Rastrococcus invadens</i> Williams		no	major threat	Williams 1986	mango	AF(?)

Table 1. Continued.

Pest or Threat species	U.S. Origin and Date of Introduction	Established in U.S.	Pest or Threat Status in U.S.	Reference to Threat on Pest Status	Principle Hosts	Origin
<i>Rastrococcus spinosus</i> (Robinson)		no	minor threat	Le Pelley 1968	coffee	AF(?)
<i>Rastrococcus truncatispinus</i> Williams		no	threat	Williams 1985a	citrus	AU
<i>Rastrococcus victorum</i> Williams and Watson		no	threat	Williams and Watson 1988	citrus	AU(?)
<i>Rhizococcus albidus</i> Goux	FL, 1959	no	minor threat	Williams 1962	grasses	PA
<i>Rhizococcus americanus</i> (Hambleton)		yes	pest	Hambleton 1976	polyphagous	NT
<i>Rhizococcus andensis</i> (Hambleton)		no	threat	Watson and Cox 1990	coffee	AF
<i>Rhizococcus cactaceus</i> (Hambleton)		yes	pest	Dziedzięka 1990	polyphagous	NE(?)
<i>Rhizococcus cabelopus</i> Williams	native ?	no	threat	Williams 1987b	polyphagous	AU
<i>Rhizococcus cocots</i> Williams		no	minor threat	Williams 1985b	coconut	AU
<i>Rhizococcus dianthi</i> Green	CA, 1954	yes	pest	Saetsinger 1966	polyphagous	PA(?)
<i>Rhizococcus epicropus</i> (Williams)		no	threat	Williams and Granara de Willink 1992	sugar cane	NT
<i>Rhizococcus falcifer</i> Kueckel d'Hercolais	CA, 1917	yes	pest	Cox 1987	polyphagous	PA
<i>Rhizococcus tubisci</i> Kawai and Takagi	FL, 1978	yes	pest	Kawai and Takagi 1971	polyphagous	PA
<i>Rhizococcus kondonis</i> Kuwana	CA, 1921	yes	pest	Godfrey and Pickel 1998	alfalfa	PA
<i>Rhizococcus nemoralis</i> (Hambleton)		no	minor threat	Watson and Cox 1990	coffee	NT
<i>Rhizococcus ramicis</i> (Maskel)		no	threat	Williams 1985a	grass	AU(?)
<i>Rhizococcus saintpauliae</i> Williams		no	threat	Williams 1985c	African violets	OR
<i>Rhodania porifera</i> Goux		no	minor threat	Ter-Grigorian 1973	Festuca	PA
<i>Saccharicoccus sacchari</i> (Cockerell)	FL, 1944	yes	minor pest	Ben-Dov 1994	sugar cane	NT(?)
<i>Spilococcus andersoni</i> (Coleman)	native	yes	pest	Brown and Fads 1967	Monterey cypress	NE
<i>Spilococcus manillaruae</i> (Bouche)	CA, 1938	yes	pest	Manichote and Middlekauff 1967	cactus	NE
<i>Tridiscus sporoboli</i> (Cockerell)	native	yes	pest	Baxendale et al. 1994	buffalograss turf	NE
<i>Trionymus hauchoni</i> McKenzie	native	yes	pest	Osborn 1952	barley	NE
<i>Trionymus multivorus</i> (Kiritschenko)		no	minor threat	Myatseva and Kharchenko 1987	grass and lettuce	PA
<i>Trionymus polyvorus</i> Hall		no	threat	Willcocks 1925	grains	PA
<i>Trionymus radicecola</i> (Morrison)		no	threat	Stahl 1927	sugar cane	OR
<i>Trionymus violascens</i> Cockerell	native	yes	pest	Cockerell and Robinson 1915	grass	NE
<i>Bryburgia anaryllidis</i> (Bouche)	CA, 1960	yes	minor pest	Ben-Dov 194	lilies	AF
<i>Vryburgia brevicurvis</i> (McKenzie)	CA, 1935	yes	pest	McKenzie 1967	polyphagous	AF
<i>Vryburgia rimariae</i> Tramaglia		no	threat	Marotta and Garonna 1992	succulents	AF
<i>Vryburgia transvaalensis</i> (Bram)		no	threat	Bram 1929	ornamentals	AF
<i>Vryburgia trionymoides</i> (De Lotto)	CA, 1994	yes	minor pest	Gill, in press	<i>Caralluma</i>	AF
<i>Xenococcus acropygus</i> Williams		no	threat	Williams 1998	grape	OR

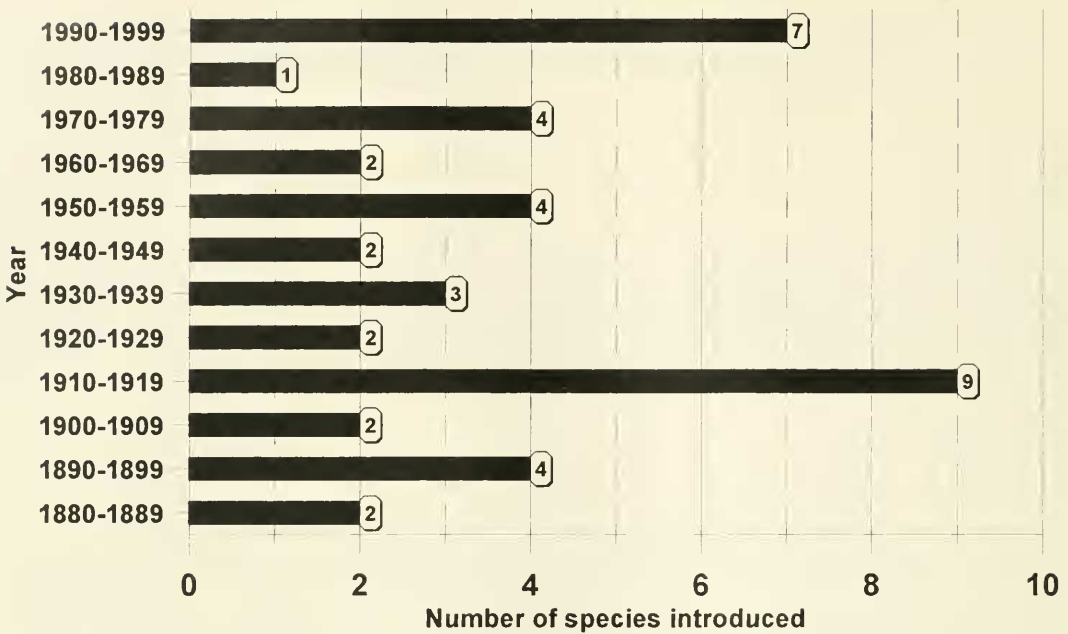


Fig. 1. Introduction of mealybug pests into the United States from 1880–1999.

350 species of mealybugs in the United States; thus, the adventive component of the mealybug fauna in the United States is approximately 13%. With the exception of the 1980's, every decade since the 1880's has seen the introduction of at least 2 species of mealybug pests (Fig. 1). Two periods, the 1910's and the 1990's, witnessed the greatest number of introduced mealybug pests (9 and 7 species, respectively).

A summary of the area of origin of all invasive species in the United States is as follows: Palearctic Region—17 U.S. invaders, 4 of which are considered non-pest adventives; Neotropical Region—12 U.S. invaders, none are considered non-pest adventives; Oriental Region—7 U.S. invaders, one is considered a non-pest adventive; Australasian Region—4 U.S. invaders, one is considered a non-pest adventive; Afrotropical Region—3 U.S. invaders, none are considered non-pest adventives; and Nearctic Region outside of the U.S.—4 U.S. invaders, none are considered non-pest adventives.

Examination of the origin of pest mealy-

bugs worldwide provides the following totals: from the Palearctic Region, 46; Nearctic Region, 27; Neotropical Region, 25; Oriental Region 23; Afrotropical Region, 19; and from the Australasian Region, 18. Host characteristics of these pests include: 22% polyphagous; 20% on grasses; 16% on citrus/tropical fruits; 6% on coffee; and the remainder are not polyphagous and occur on various other hosts. Based on the characteristics of the highest pest mealybug distributions and greatest frequency of host plants, a list of 10 species most likely to invade the United States has been determined. These species include: *Cataenococcus hispidus* (Morrison), *Dysmicoccus neobrevipes* Beardsley, *Heliococcus bohemicus* Šulc, *Nipaeococcus viridis* (Newstead), *Phenacoccus avenae* Borchsenius, *Phenacoccus azaleae* Kuwana, *Planococcus lilacinus* (Cockerell), *Planococcus minor* (Maskell), *Pseudococcus cryptus* Hempel, and *Rastrococcus iceryoides* (Green).

Interception records from the past five years from the USDA, APHIS-PPQ also were searched. A list of the 10 species in-



tercepted most frequently at U.S. ports-of-entry are: *Cataenococcus hispidus* (Morrison); *Dysmicoccus hispinosus* Beardsley; *Dysmicoccus mackenziei* Beardsley; *Dysmicoccus neobrevipes* Beardsley; *Maconellicoccus hirsutus* (Green); *Palmicultor palmarum* (Ehrhorn); *Paracoccus marginatus* Williams and Granara de Willink; *Planococcus kraunhiae* (Kuwana); *Planococcus lilacinus* (Cockerell); and *Planococcus minor* (Maskell). Comparison of the two lists reveals four species that are common to both. They are: *Cataenococcus hispidus*; *Dysmicoccus neobrevipes*; *Planococcus lilacinus*; and *Planococcus minor*. We suggest that these species are most likely to be the next invasive mealybugs into the United States.

#### DISCUSSION

Our data indicate that the decades starting in 1910 and 1990 had the largest number of mealybug introductions. We speculate that the first peak occurred because of implementation of the Plant Quarantine Act in 1912. At this time, new inspection procedures were started causing the detection of many insect contaminants in import commodities at U.S. ports-of-entry. Increased detection caused the development of strategies to reduce the risk of introduction of the potential invasive species. We suspect that the recent increase in world trade and the difficulty of inspecting large volumes of containerized imports may explain the larger number of mealybug establishments in the 1990's.

Our findings provide predictions about the most likely mealybug species to be introduced into the United States in the future and give procedures that may help others make predictions about the next invasive mealybug in other countries. Another criterion for predicting invasive species problems that was not considered here might include examination of all polyphagous species that have several agricultural hosts. A final observation: although invasive species are not always economic before they invade

a new area, examination of the list of U.S. invaders reveals that most were considered to be at least minor pests before they were invasive in the U.S.

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